APPENDIX M

Selenium Management Plan

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MOUNT POLLEY MINE

Selenium Management Plan

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REPORT

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Table of Contents

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) is pleased to provide Mount Polley Mining Corporation (MPMC) with the following Selenium Management Plan (SeMP) as a strategic framework for the management of selenium releases from the Mount Polley Mine (the Mine). The overarching goal of the SeMP is to avoid potential adverse environmental effects, using a proactive rather than reactive approach to selenium management.

The framework outlined in this SeMP is based on detailed information provided in the *Mount Polley Mine: Resumed Operations and Closure Water Management Plan. Permit Amendment Application under the Environmental Management Act: Technical Assessment Report* (the TAR). This SeMP is intended to be a living document and will be updated as new information related to site conditions and applied or tested treatment technologies becomes available. The data gathered in monitoring and investigative studies will become part of the information base for further decisions concerning selenium management at the Mine.

The strategy for managing selenium releases at the Mine considers the following phases of effluent discharge and the compliance conditions specific to each (see Section 4.0):

- approved short-term discharge (November 2015 to November 2017, or earlier)
- operations (November 2017 to closure)
- closure (July 2020)

During approved short-term discharge and operations, site water is, or is proposed to be, directed through a water treatment plant engineered to actively remove particulate constituents (as well as copper for the operations period) from the effluent. During closure, passive or semi-passive treatment technologies will be considered, where possible, and an adaptive management approach is expected to be needed to manage treated effluent quality to comply with closure effluent permit limits.

The main objectives of the SeMP are as follows:

- providing a framework to proactively protect ecological receptors from potential adverse environmental effects related to mining-related inputs of selenium from the Mine
- identifying environmental management and protection goals focussed on meeting existing or anticipated permit requirements
- supporting the proactive management of potential selenium-related issues to avoid environmental liabilities

2.0 REGULATORY CONTEXT

Selenium releases are currently a focus area for regulatory bodies as scientific understanding of the interaction of the element with receiving environments increases. British Columbia (BC) ambient Water Quality Guidelines (WQGs) establish objectives for selenium for the protection of aquatic life. The BC WQGs for selenium were updated in 2014 to provide guidelines for aquatic life, wildlife, and health-based tissue guidelines.

2.1 Relevant Guidelines for Selenium

From a regulatory perspective, selenium cannot be adequately assessed using ambient WQGs or objectives alone because the primary route of selenium effects in aquatic ecosystems is via dietary exposure to organo-selenium, rather than inorganic selenium, in the water column. WQGs for most substances are based on toxicity data generated from waterborne exposure. As such, these guidelines do not consider tissue concentrations in exposed biota, the mechanisms of toxicity in aquatic environments, or other site-specific considerations that are relevant to selenium (Chapman et al. 2010). In recognition of this limitation, BC Ministry of Environment (MoE) and the United States Environmental Protection Agency (US EPA) both have regulations for selenium that include water, sediment, and tissue-based values (Table 1). This approach aligns with the general agreement within the scientific community that a tissue-based selenium criterion is the most effective measure to define limits for the protection of aquatic life in aquatic systems (Chapman et al. 2010).

In recognition of recent developments in selenium science, the BC WQGs for selenium were updated in 2014 to include more recent information on the effects of selenium on human health and ecological receptors. The updated BC WQGs for selenium established guideline values for fish and bird eggs, whole body fish tissue, fish muscle tissue, and invertebrate tissues that range from 4 to 11 milligrams per kilograms dry weight (mg/kg dw) (MoE 2014a). US EPA aquatic life water quality criteria for selenium were revised in 2016. The updated US EPA regulatory values provides a two-part criterion that specifies selenium concentrations in fish tissue (eggs or ovaries and whole body or muscle) and waterborne screening values of 1.5 µg/L for lentic systems and 3.1 µg/L for lotic systems (US EPA 2016).

Table 1: Relevant Regulatory Guidelines for Selenium: Interim and Approved

Water Use	Guideline for Total Selenium
Approved and Interim Guidelines and Criteria[a]	
BC Aquatic Life (freshwater)	1 µg/L (alert concentration); 2 µg/L (guideline)
BC Aquatic Life (fish tissue)	11 mg/kg dw (egg/ovary); 4 mg/kg dw (whole body); 4 mg/kg dw (muscle; interim)
BC Aquatic Life (invertebrate tissue)	4 mg/kg dw (interim)
BC Aquatic Life (sediment)	2 mg/kg (dw; alert concentration)
BC Wildlife (freshwater)	2 µg/L
BC Wildlife (bird eggs)	6 mg/kg dw
BC Irrigation Water	10 µg/L
BC Livestock Watering	30 µg/L
BC Drinking Water	10 µg/L
Canadian Drinking Water[b]	50 µg/L
US EPA Drinking Water[c]	50 µg/L
WHO Drinking Water[d]	40 µg/L (20% of safe upper intake)
US EPA (freshwater)[e]	3.1 µg/L (lotic systems); 1.5 µg/L (lentic systems)
US EPA (fish tissue) [e]	15.1 mg/kg dw (egg/ovary); 8.5 mg/kg dw (whole body); 11.3 mg/kg dw (muscle)

a) Ambient Water Quality Guidelines for Selenium Technical Appendix Update (MoE 2014a), unless specified otherwise.

b) Health Canada (2014) Guidelines for Canadian Drinking Water Quality.

c) US EPA (2009) National Primary Drinking Water Regulations.

d) WHO (2011) Selenium in Drinking-water.

e) Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater 2016 (US EPA 2016).

dw = dry weight; BC = British Columbia; US EPA = United States Environmental Protection Agency; WHO = World Health Organization.

BC WQGs also set limits for selenium in drinking water, with a guideline of 10 micrograms per liter (µg/L), based on a previous Health Canada guideline. The current Canadian WQG for selenium in drinking water is 50 µg/L (Health Canada 2014). The World Health Organization (WHO 2011) reports that water is not normally a major source of selenium intake for humans, and at levels below 50 µg/L it would be unusual for drinking water to make a significant contribution to total selenium intake. When setting guideline values for selenium in drinking water, the WHO suggests allocating 20% of the safe upper intake level of 400 µg/day to drinking water, which translates to a value of 40 µg/L, assuming an intake of 2 L/day.

Canadian, BC, US EPA, and WHO drinking water guidelines and BC WQGs are presented in Table 1.

2.2 Derivation of Site Performance Objectives and Science-Based Environmental Benchmarks

It has been recognized by MoE (2014b) that in some cases, WQGs may not be appropriate thresholds to assess environmental effects because WQGs were derived to be protective of all waters of BC and do not take into account site-specific conditions that may modify exposure and toxicity. Under these circumstances, it may be appropriate to develop an alternative threshold, such as a science-based environmental benchmark (SBEB), to account for site-specific conditions, which often forms the basis of an approved site performance objective (SPO). An SBEB is defined as "a quantifiable receiving environment parameter or attribute developed by qualified professionals through a rigorous scientific process with the intent to guide management decisions for a regulated activity at a specific location" (MoE 2014b). An SPO is a quantifiable receiving environment parameter or attribute, set by a statutory decision-maker considering scientific information along with other factors. For selenium in particular, the BC WQG was derived to be protective of aquatic life in the most sensitive lentic environments. Site-specific studies at other mines in BC have supported the derivation of SBEBs and approval of SPOs for selenium higher than the BC WQG where lentic environments are limited or absent. While the updated BC WQGs include guidelines for selenium concentrations in biological tissue, SBEBs and SPOs are defined as aqueous selenium concentrations for the purpose of facilitating selenium management.

The objective of deriving SPOs is twofold. First, these values can be used to evaluate predicted future selenium concentrations in receiving waters. In this context, predicted selenium concentrations exceeding an SPO would trigger investigations to refine the effects assessment or indicate a need for further mitigation. Second, SPOs provide a target to be used in scoping and designing further mitigation to reduce selenium concentrations in Mine wastewater, and to evaluate the success of these mitigation measures in attaining protection of receiving water ecosystems.

3.0 PREDICTED SELENIUM RELEASES

As discussed in the TAR, predicted selenium concentrations in Mine contact water that will be treated and discharged to Quesnel Lake, as well as in Springer Pit water that may migrate as seepage toward Bootjack Lake, were higher than the 30-day BC WQG. There is no aquatic life WQG specific to protection against selenium effects from acute exposures because diet is the primary pathway of selenium exposure to aquatic life. However, for the purposes of this effluent quality assessment, acute toxicity data compiled in the selenium BC WQG technical guidance (MoE 2014a) to support the derivation of the 30-day BC WQG were reviewed. The lowest reported acute toxicity value for rainbow trout (*Oncorhynchus mykiss*) documented was 4,500 µg/L as selenite, which was selected as an acute screening value. The highest predicted 95th percentile concentrations of total selenium in the treated effluent discharge (87 µg/L) and in the Springer Pit seepage (61 µg/L) were less than this acute screening value, as was the proposed treated effluent discharge limit of 75 µg/L for operations. Selenium will be managed as described in this SeMP, such that concentrations of selenium in effluent discharged to Quesnel Lake remain less than 75 µg/L, and the in-lake monthly average concentration, at the edge of the initial dilution zone (IDZ), remains less than 2 µg/L to meet BC WQGs.

As discussed in the TAR, predicted selenium concentrations at the edge of the IDZ in Quesnel Lake and Bootjack Lake are less than the 30-day BC WQG of 2 µg/L for the protection of aquatic life (maximum median concentration of 1.4 µg/L and maximum 95th percentile of 2.0 µg/L for Quesnel Lake and maximum median concentration of 0.96 µg/L and maximum 95th percentile of 1.6 µg/L for Bootjack Lake).

During closure, drainage of Mine contact water may be permitted to return to the natural hydrology of waterbodies and water courses around the Mine. Contact water may be diverted through treatment systems before being released to natural catchments. Depending on the selected closure/post-closure water management approach, if passive treatment systems are implemented, even if best available technologies (BATs) for passive treatment are applied, selenium concentrations in treated source water may exceed the BC WQG of 2 µg/L for the protection of aquatic life.

4.0 COMPLIANCE AND ENVIRONMENTAL PROTECTION GOALS

The strategy for managing selenium releases at the Mine is to achieve compliance and environmental protection goals specified for the following periods of effluent discharge.

4.1 Approved Short-Term Discharge

MPMC is currently permitted to, and proposes to continue to, discharge treated effluent to Quesnel Lake via the Hazeltine Channel until the end of November 2017. As described in the short-term Technical Assessment Report (Golder 2015), Hazeltine Creek presently is not fish habitat because fish access has been restricted with barriers to facilitate the ongoing rehabilitation activities following the 2014 tailings storage facility foundation failure. For the purpose of the short-term discharge of effluent, Hazeltine Creek is not considered a receiving environment and will be considered as a conduit for surface water flow into Quesnel Lake. This is applicable for the short term only because the objectives for Hazeltine Creek rehabilitation include its future use by fish and other aquatic biota.

The selenium management goals for the short-term discharge via Hazeltine Channel (until November 2017) are as follows:

- Attain permit compliance at discharge location HAD-03 by meeting the approved effluent limit for selenium. The effluent limit is presently 60 µg/L, which is higher than the BC WQG for aquatic life and was approved based on rationale that no fish are permitted in Hazeltine Creek during this period of discharge and that WQGs are met at the edge of the IDZ.
- Attain environmental protection at the edge of the IDZ in Quesnel Lake by meeting BC WQGs.

4.2 Operations

After November 2017, the effluent discharge is proposed to be transitioned to a pipeline directly connecting the water treatment plant to Quesnel Lake. This change in discharge method would eliminate effluent discharge to Hazeltine Creek, which will enable the creek to be restored to fish habitat.

The selenium management goals for the discharge during operations (nominally from November 2017 through to closure) are as follows:

- Attain permit compliance at the discharge location (end-of-pipe) by meeting the approved effluent limit for selenium. The effluent limit may need to be re-evaluated with time based on results of effluent and receiving-environment monitoring. The compliance point for selenium will be end-of-pipe because an in-lake compliance point at the edge of the IDZ in Quesnel Lake may present logistical difficulties for frequent monitoring, particularly during the winter months.
- Attain environmental protection at the edge of the IDZ in Quesnel Lake by meeting BC WQGs.

4.3 Closure

During closure, contact water may be diverted through decentralized passive treatment systems before being released to natural catchments of the Mine area, depending on results of pilot-scale testing, ongoing review of emerging BATs and passive treatment alternatives, and refinement of water quality and quantity models for the Mine. Even if BATs for closure are applied, selenium concentrations in treated source water may exceed the BC WQG of 2 µg/L for the protection of aquatic life.

The selenium management goals for discharge during closure are as follows:

- Attain environmental protection in Quesnel, Bootjack, and Polley lakes by meeting BC WQGs at the edge of the IDZ within each lake. These lakes have sufficient dilution that selenium concentrations less than WQGs will be achieved at the edge of the IDZ.
- Attain environmental protection in Hazeltine Creek by meeting an SPO approved by MoE for Hazeltine Creek for closure. An SPO higher than the BC WQG of 2 µg/L that is still considered to be protective of aquatic life will be proposed in consultation with MoE and supported by field studies and data analysis.

For the purpose of closure planning for the Mine, Golder (2016) (Appendix F of the TAR) proposed a treatment target of 10 µg/L for effluent discharged to Hazeltine Creek during closure. This concentration was shown to provide an appropriate level of protection to aquatic life in receiving waters in other mine areas of BC. For releases to Hazeltine Creek during closure, it has been conservatively assumed that there will be no dilution of treated contact water, because the dilution capacity of the creek is limited by seasonal flow. Therefore, a total selenium concentration of 10 µg/L, if met in Hazeltine Creek, would not be expected to cause adverse effects to resident aquatic life.

It is understood that development and approval of a permit limit for selenium or an in-stream SPO for Hazeltine Creek for closure will require further consultation with MoE prior to closure. Planning for monitoring to support this work will be discussed with MoE prior to undertaking the work.

5.0 MANAGEMENT, MITIGATION, AND CONTINGENCY MEASURES

A geochemical characterization of the Mine site has been completed to determine which areas of the Mine have the highest potential for loading of selenium into the environment. These sources have been incorporated into a site water quality model (WQM) to predict Mine effluent quality during operations and into post-closure (Appendix D of the TAR). Two scenarios were evaluated as part of the WQM, Scenario 1 used Mine monitoring data as inputs and Scenario 2 used source terms developed by SRK Consulting (Appendix C of the TAR). Scenario 1 was considered to be more representative of operations water quality than Scenario 2 because the main conditions driving source water chemistry (e.g., water management practices, pH and redox state of Mine materials) are not expected to change for the remainder of operations. Scenario 2 predictions were based on the assumption that Mine drainages are at their solubility limits (i.e., are at the upper end of expected concentrations). The modelling indicates that selenium treatment will not be required during operations if concentrations remain within the ranges currently recorded in the existing environmental monitoring data, but treatment may be required if Mine drainages approach their solubility limits.

Selenium is currently managed through a combination of best applicable practices (BAPs). BAPs currently in place, and those that will be considered for future implementation, include the following:

- **Water management**—The mine plan includes water management structures designed to divert non-contact water away from waste materials.
- **Progressive reclamation**—Waste dumps will be reclaimed once they reach capacity, which for many dumps means they will be fully reclaimed prior to closure.
- **Pit backfill**—The Cariboo-Springer Pit will be used to subaqueously store potentially acid generating waste, which reduces the exposure of potentially acid generating rock and pit walls to oxygen, thereby reducing potential selenium loading from oxidation of these materials.
- **Engineered cover**—The feasibility of engineered cover systems over waste rock piles may be investigated. Engineered cover systems are designed to reduce the infiltration of water into the waste piles or to reduce the ingress of oxygen. The weathering of sulphide minerals that contribute to the loading of selenium and sulphate requires both oxygen and water. If one of these is not present, the weathering reaction will not proceed and selenium and sulphate will not be released to the receiving environment from oxidation of waste rock. The design and site-specific performance of the cover will dictate how effective it is at reducing selenium and sulphate loading.
- **In-pit treatment**—Flooded mined-out pits may be considered as a method to reduce selenium in waters containing elevated concentrations of this parameter, if required during operations and/or for closure.
- **Biological treatment**—passive systems such as the biochemical reactor (Baldwin et al. 2015) that was piloted on site may be employed to mitigate selenium and other constituent concentrations in Mine contact waters.

Management and treatment of selenium is a developing science, with ongoing research into the topic being carried out worldwide. BATs are technologies that have been researched and are considered to be achievable to implement at the Mine. Based on these, a conceptual passive water treatment system has been designed to remove sulphate and selenium during post-closure (Appendix F of the TAR). A pilot system to trial this technology has also been designed, which could be constructed and tested during operations as one possible use of BAT for water (and selenium) management at the Mine during closure.

This conceptual passive water treatment system includes a biochemical reactor to remove selenium, along with other key constituents, to treat effluent to within proposed discharge targets. The bio-chemical reactor consists of a lined pond filled with carbon source substrate and submerged water column, where oxygen is consumed by microorganisms, and anaerobic conditions prevail. The anaerobic conditions are ideal for development of microorganisms that use organic substrate as a nutrient source, such as sulphate and selenium. Further information on these systems is included in Appendix F of the TAR.

6.0 RECOMMENDED MONITORING

Monitoring of selenium in effluent and the receiving environment is necessary to confirm permit compliance and that environmental protection goals are achieved. The following sections provide an overview of recommended monitoring in support of selenium management for the different phases of effluent discharge. Monitoring of aqueous selenium concentrations is typically undertaken as part of routine monitoring for the effluent discharge (MPMC 2016; the TAR). Additional monitoring that could be undertaken in support of a selenium management plan is described below.

6.1 Short-Term Discharge

Recommended monitoring of selenium during the short-term discharge is as follows:

- Per the requirements of amended Permit 11678, monitoring is conducted at discharge location HAD-03 to confirm compliance with the approved effluent permit limit for selenium (60 µg/L). Monitoring is presently conducted at the edge of the IDZ in Quesnel Lake (QUL-58) to confirm that selenium remains below the WQGs and it is recommended that monitoring be continued.
- To take advantage of current conditions of effluent in Hazeltine Creek, it is recommended that monitoring be undertaken to characterize selenium bioaccumulation in biota both upstream and downstream of the effluent discharge location. It is recommended that this monitoring be undertaken in 2016 and/or 2017 in Hazeltine Creek to support the proposed treatment target of 10 µg/L for effluent discharged to Hazeltine Creek during closure.

6.2 Operations

If the pipeline to Quesnel Lake is approved, recommended monitoring of selenium during operations, is as follows:

- Monitoring will be required at the new discharge location (end-of-pipe) to confirm compliance with the effluent permit limit. It is recommended to continue monitoring at the edge of the IDZ in Quesnel Lake (QUL-58) to confirm that WQGs are met.
- After direct discharge to Hazeltine Creek ceases, monitoring in Hazeltine Creek upstream and downstream of the previous discharge location is recommended to confirm that water quality no longer reflects an influence from the treated discharge. Sampling would entail water chemistry and tissue concentrations in biota, with sampling frequency to be informed by preliminary results collected during the short-term discharge.
- Fish are presently excluded from Hazeltine Creek by physical barriers in place during the creek rehabilitation and the approved short-term discharge of treated effluent. Once fish habitat and access in Hazeltine Creek are restored, it would be prudent to undertake limited sampling of resident fish to monitor fish exposure to selenium.

6.3 Closure

Recommended monitoring of selenium during closure is as follows:

- Monitoring will likely be required at the discharge locations (end-of-pipe) during closure to confirm compliance with future, discharge-specific effluent permit limits. Monitoring at the edge of the IDZ in lake receiving environments (i.e., Quesnel, Polley, and Bootjack lakes) should also be undertaken to confirm that WQGs are met.
- Monitoring in Hazeltine Creek near to, or downstream of, the discharge locations will be undertaken (if discharge to Hazeltine Creek is proposed and approved) to confirm that the in-stream SPO (if applicable) is met. Supplemental monitoring of biota in Hazeltine Creek may be recommended in support of the SPO.

7.0 CLOSURE

We trust that the information provided in this technical memorandum is sufficient for your present needs. If you have any questions, please do not hesitate to contact the undersigned at (604) 296-4200.

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